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ASSESSING VEGETATION CHANGES IN RESPONSE TO CLIMATE VARIABILITY: A CASE STUDY OF THE CHARVAK REGION

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ABSTRACT--
This study investigates long-term vegetation dynamics in the Charvak Reservoir region of Uzbekistan during the 1991–2020 climatic period, using NDVI time series derived from Landsat satellite imagery. By comparing summer-season NDVI composites for 1991 and 2020, we identified spatial patterns of vegetation gain and loss. The results show a predominant greening trend across the basin, particularly in foothill and riparian areas, while localized zones exhibited NDVI decline. To understand the drivers of these changes, we analyzed regional climate data, revealing a significant warming trend (+0.04 °C/year) and a concurrent decline in annual precipitation (–8.6 mm/year). These climatic shifts likely contributed to extended growing seasons and altered hydrological regimes. The integration of remote sensing and climate datasets demonstrates the effectiveness of satellite-based monitoring for evaluating vegetation response to environmental variability in mountainous reservoir landscapes. The findings underscore the importance of continued observation in the context of climate change and ecosystem resilience.

KEYWORDS: *NDVI, Vegetation Dynamics, Climate Change, Charvak Reservoir, Landsat, Climatic Period 1991–2020*--

1. INTRODUCTION

Monitoring vegetation dynamics using remote sensing indices such as NDVI (Normalized Difference Vegetation Index) has become increasingly important in the context of global and regional climate change [1]. Vegetation cover, recognized as an essential climate variable, influences energy and water exchange between land and atmosphere, and responds sensitively to both natural and anthropogenic drivers [2]. In mountainous and semi-arid regions, shifts in temperature and precipitation regimes are altering growing season characteristics, resulting in both greening trends and localized degradation, with implications for biodiversity and ecosystem resilience [2–4]. Remote sensing enables the detection of such long-term vegetation changes across large areas [5]. In climatology, 30-year periods are widely accepted as standard climatic normals, following WMO guidelines. The most recent complete period, 1991–2020, is marked by accelerated warming, altered rainfall patterns, and more frequent extreme events [6]. This makes it particularly relevant for evaluating vegetation dynamics in sensitive regions like the Charvak Basin. This study aims to assess NDVI-based vegetation changes in the Charvak Reservoir area during 1991–2020, identify spatial patterns of degradation and greening, and link these to regional climate variability.

2. DATA AND METHOD

2.1. Study area

The Charvak Reservoir is located in the western Tian Shan Mountains of northeastern Uzbekistan, within a geodynamically active region characterized by ongoing intracontinental deformation of the Eurasian lithospheric plate. The reservoir was created at the junction of three major rivers — the Chatkal, Pskem, and Koksu — and spans an area of approximately 37.3 km², reaching depths of up to 150 meters. This mountainous area lies within a complex tectonic zone intersected by several major fault systems, including the Pskem, Kumbel-Kokand, Ugam, and Chatkal faults. The presence of these deep-seated structures contributes to the region's high seismic hazard and elevates the risk of processes such as reservoir-induced seismicity and shoreline instability. These geodynamic conditions, combined with altitudinal gradients and climatic variability, make the Charvak basin a suitable site for studying vegetation responses to environmental change (Figure 1).

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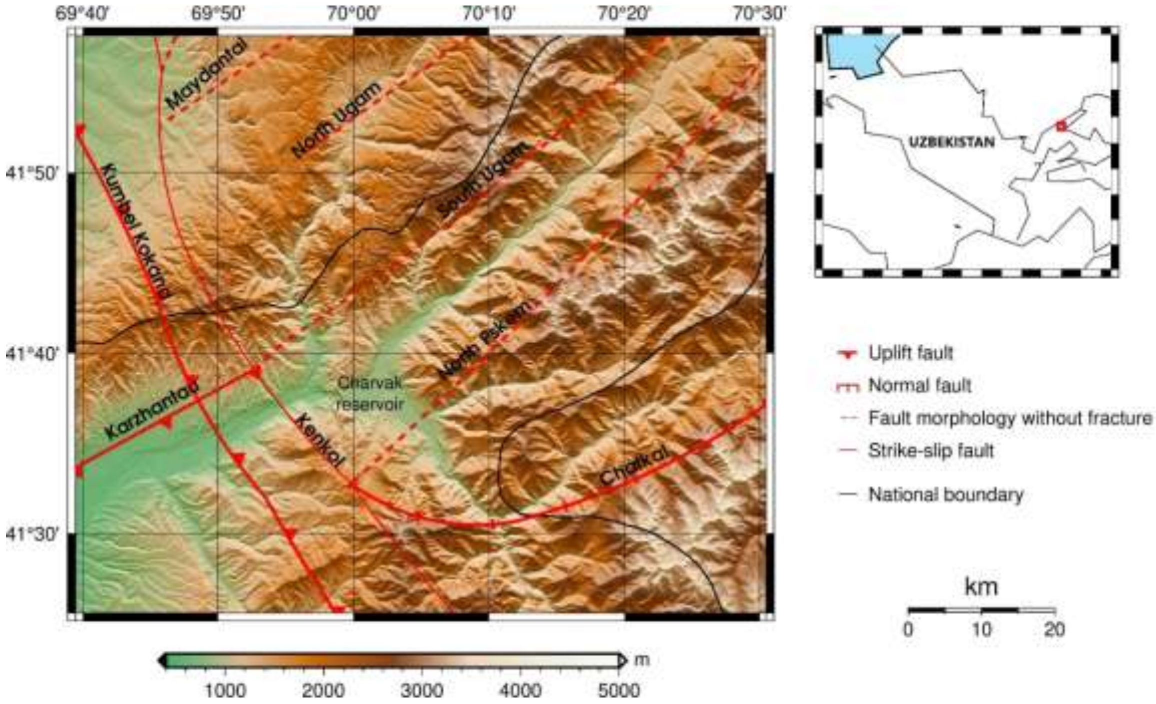

Figure 1. Study area map showing the boundaries of the Charvak Reservoir region in northeastern Uzbekistan.

2.2 Data and Processing

This study utilized surface reflectance products from the Landsat Collection 2, Tier 1, Level-2 datasets. Two specific years were selected to represent the beginning and end of the latest climatic normal:

- Landsat 5 TM (Thematic Mapper) for 1991,
- Landsat 8 OLI (Operational Land Imager) for 2020.

Both datasets were filtered for the summer season (June to September) to capture peak vegetation activity while minimizing phenological and cloud-related variability. Surface reflectance values were scaled using the standard radiometric calibration: $SR = DN \times 0.0000275 - 0.2$

NDVI was calculated using the normalized difference between near-infrared and red bands:

- For Landsat 5: $NDVI = (SR\_B4 - SR\_B3) / (SR\_B4 + SR\_B3)$
- For Landsat 8: $NDVI = (SR\_B5 - SR\_B4) / (SR\_B5 + SR\_B4)$

For each year, a median summer composite was generated. These composites were then clipped to the study area and used to compute the NDVI difference (ΔNDVI) between 2020 and 1991. Areas with ΔNDVI < –0.05 were classified as degraded zones. These were vectorized, and the largest degradation polygon was automatically extracted for detailed temporal analysis.

2.3 Climatic Data

To evaluate climate-vegetation interactions, two key variables were considered: annual precipitation and mean annual surface temperature for the period 1991–2020. Annual precipitation was derived from the CHIRPS (Climate Hazards Group InfraRed Precipitation with Station data) dataset, which offers daily rainfall estimates at 0.05° spatial resolution. We extracted CHIRPS data over the study region and aggregated daily values into yearly totals. Mean precipitation was calculated by spatially averaging the annual raster for each year over the Charvak basin. The resulting 30-year time series enabled trend analysis of rainfall variability.

Temperature data were obtained from the ERA5-Land reanalysis dataset, produced by the European Centre for Medium-Range Weather Forecasts (ECMWF). ERA5-Land provides hourly temperature estimates at ~9 km spatial resolution. We calculated mean annual temperature by averaging daily temperature values for each year and regionally aggregating them across the study area. This allowed for the construction of a consistent time series suitable for detecting long-term warming trends.

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Both climate variables were visualized as line plots with fitted linear regressions to evaluate their role in driving observed NDVI trends.

3. RESULTS AND DISCUSSION

The spatial analysis of NDVI dynamics between 1991 and 2020 reveals pronounced changes in vegetation cover in the Charvak Reservoir region. The classified NDVI maps for the summer of 1991 and 2020 (Figure 2, top and middle) show a clear shift towards higher vegetation density in many parts of the study area. In 1991, vast zones around the reservoir exhibited moderate NDVI values (0.16–0.33), indicating sparse vegetation cover, while areas with high NDVI (>0.5) were limited to isolated patches primarily in riparian zones and higher altitudes. By contrast, the 2020 NDVI map demonstrates a significant expansion of dense and moderately dense vegetation (NDVI > 0.34), especially in the southwestern and central parts of the basin.

The NDVI change map (Figure 2, bottom) illustrates the difference in NDVI values between 2020 and 1991. The most prominent observation is the widespread positive NDVI trend, with many areas experiencing increases of more than +0.2 (highlighted in red). These zones of greening are especially concentrated in the southern slopes, foothill valleys, and areas adjacent to river systems.

Possible explanations include improved water availability due to changes in snowmelt regimes, land abandonment in marginal agricultural areas, or natural vegetation recovery following climate-induced reductions in grazing pressure. Conversely, isolated areas of negative NDVI trends (< –0.1) were identified (shown in blue and orange), mostly along steep slopes and near the reservoir shoreline.

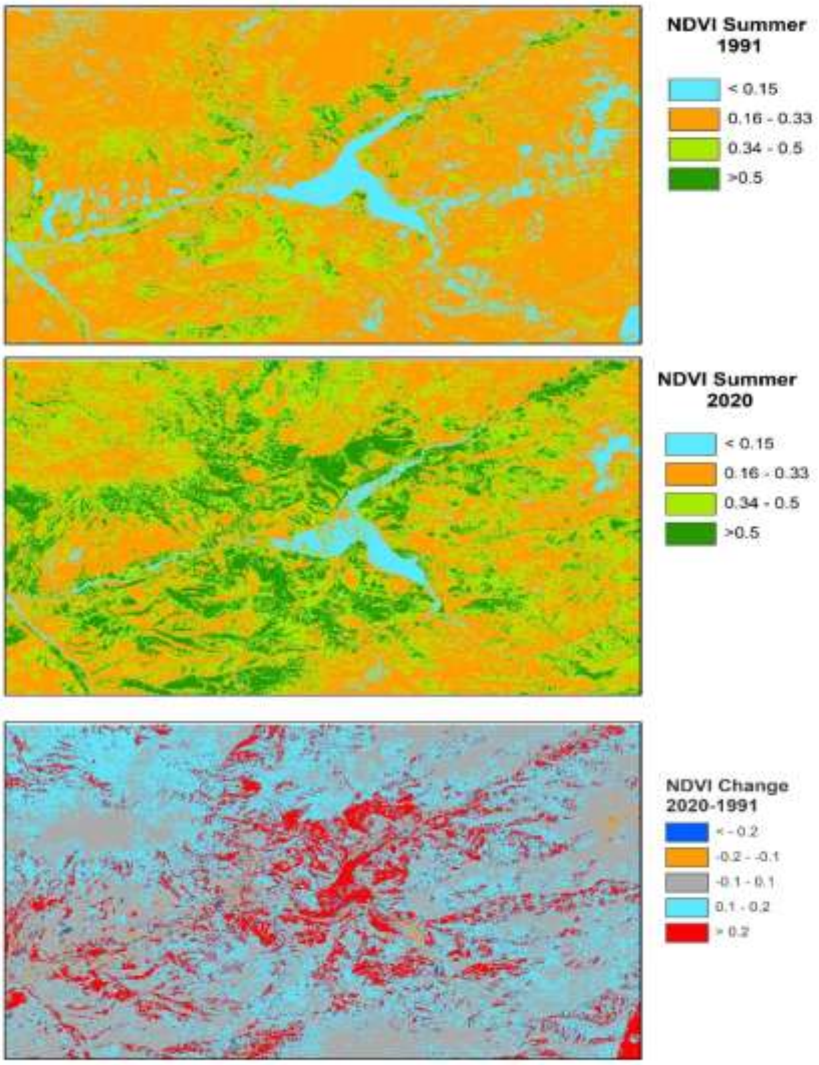

Figure 2. NDVI maps for 1991, 2020, and their difference.

These zones may indicate vegetation stress due to erosion, shallow landslides, increased tourism or recreational development, or shifting hydrological conditions, such as reservoir level fluctuations. However, such areas are considerably less extensive than those showing vegetation gain.

The observed trends are consistent with broader regional studies in Central Asia, which have documented greening of mid-mountain ecosystems linked to temperature increases and extended growing seasons [2-3]. These findings suggest that the Charvak basin has undergone substantial vegetation recovery over the past 30 years, despite being located in a tectonically and climatically sensitive zone, as reported in national climate assessments [7]. While this greening trend may reflect improved ecosystem functioning, continued monitoring is essential to assess the long-term sustainability of vegetation gains under future climate scenarios and increasing anthropogenic pressures.

These observed vegetation dynamics are closely linked to regional climatic trends during the 1991–2020 period. As illustrated in Figure 3, the average annual temperature in the Charvak region increased steadily, with a linear trend slope of +0.0406°C per year, indicating a clear warming signal.

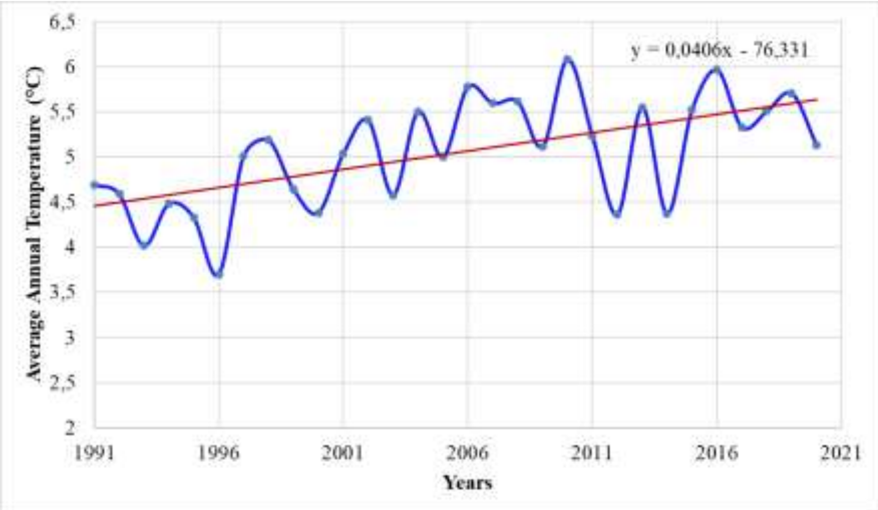

Figure 3. Average annual temperature (°C) in the Charvak region from 1991 to 2020. The linear trend (y = 0.0406x – 76.331) shows a consistent warming trend across the entire climatic period

Simultaneously, mean annual precipitation showed a declining trend of –8.62 mm per year, as seen in Figure 4. This combination of warming and drying represents a typical pattern of climate-induced stress in mountainous ecosystems.

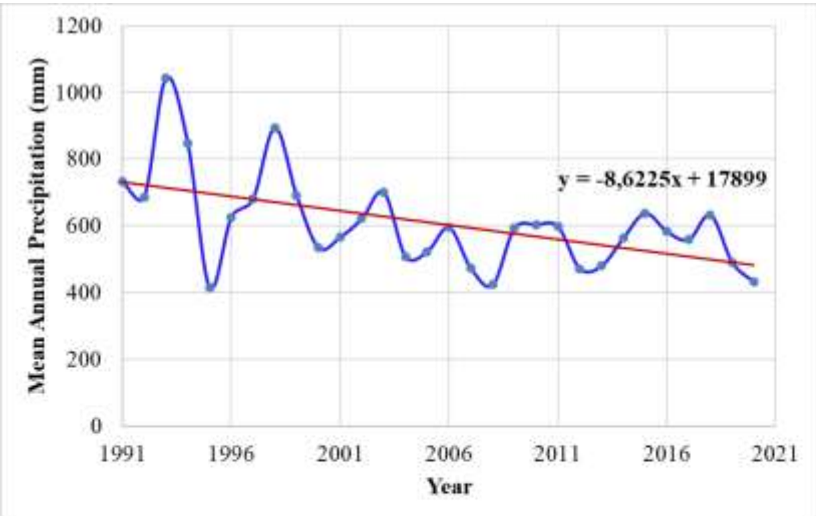

Figure 4. Mean annual precipitation (mm) in the Charvak region from 1991 to 2020. The fitted trend line (y = –8.6225x + 17899) indicates a statistically significant decrease in precipitation over the 30-year climatic period

Despite the reduction in precipitation, the widespread greening detected via NDVI may reflect improved photosynthetic activity due to elevated temperatures, longer growing seasons, or redistribution of water availability through earlier snowmelt and runoff. Similar responses have been reported in other mid-altitude regions, where warming outweighs precipitation decline in driving net vegetation productivity [2-3].

However, this apparent resilience may mask underlying vulnerabilities. Continued temperature rise, coupled with prolonged moisture deficits, could increase evapotranspiration rates and eventually lead to vegetation stress, degradation, or shifts in species composition. Therefore, the positive NDVI trend observed in this study should be interpreted with caution, and ongoing monitoring is necessary to assess the sustainability of current ecosystem trajectories under future climate scenarios.

4. CONCLUSIONS

This study assessed the dynamics of vegetation cover in the Charvak Reservoir region during the 1991–2020 climatic period using NDVI time series derived from Landsat imagery. The analysis revealed a general greening trend, with significant increases in NDVI values across much of the study area. The observed vegetation gain was particularly evident in foothill and riparian zones, where NDVI increased by more than 0.2 in some locations. The results also showed a clear warming trend in the region, with average annual temperature increasing by approximately 0.04 °C per year. At the same time, annual precipitation decreased at a rate of about 8.6 mm per year. These climatic shifts, characterized by warmer and drier conditions, appear to have contributed to vegetation changes by extending the growing season and altering water availability. Despite the overall greening trend, certain localized zones experienced NDVI decline, potentially due to erosion, slope instability, or anthropogenic impacts. These areas highlight the need for targeted monitoring and land management strategies in sensitive parts of the basin.

The combination of satellite-derived vegetation indices and climate data has proven effective for capturing long-term environmental change. The findings underscore the importance of continued Earth observation to monitor ecosystem resilience and to support adaptive management in mountainous reservoir landscapes under accelerating climate change.

REFERENCES

1. *Huang, K., Zhang, Y., Liang, H., & Guo, X. (2017). "Changes in vegetation growth dynamics and relations with climate over China's landmass from 1982 to 2011," Remote Sensing of Environment, Vol. 192, pp. 12–21.*
2. *Gennaro, S., Cerrato, R., Salvatore, M. C., Salzano, R., Salvatori, R., & Baroni, C. (2023), "NDVI analysis for monitoring land-cover evolution on selected deglaciated areas in the Gran Paradiso Group (Italian Western Alps)," Remote Sensing, Vol. 15, Article 3847. https://doi.org/10.3390/rs15153847*
3. *Im, S. T. (2024), "Evaluation of climatic influences on NDVI dynamics in Khakassia," Current Problems in Remote Sensing of the Earth from Space, Vol. 21, No. 2, pp. 156–165. https://doi.org/10.21046/2070-7401-2024-21-2-156-165*
4. *Li, X., Chen, J., & Wang, J. (2023), "Structure and function of vegetation during ecological restoration of degraded land," Frontiers in Environmental Science, Vol. 11, Article 1160101. https://doi.org/10.3389/fenvs.2023.1160101*
5. *Piao, S., Wang, X., Park, T., et al. (2019), "Characteristics, drivers and feedbacks of global greening," Nature Reviews Earth & Environment, Vol. 1, No. 1, pp. 14–27.*
6. *World Meteorological Organization (2021), State of the Global Climate 2020, WMO Report No. 1264, Geneva. Available at: https://library.wmo.int/idurl/4/56247 (accessed: 14.02.2025).*
7. *Spektorman, T. Y., & Petrova, E. V. (2006), "Climate change assessment in Uzbekistan based on output from global circulation models," Transactions of the Research Hydrometeorological Institute, Vol. 6, No. 251, pp. 41–54.*